

Article

Architectural Graphics Research: Topics and Trends through Cluster and Map Network Analyses

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Abstract: Graphic representation is a fundamental language in architecture and engineering because it facilitates the communication of any type of information. Therefore, professionals and students need continuous and updated training, with scientific references being the best source of knowledge. However, accessing the latest findings is a complex process for people in the professional world or without an extensive research background since there are no specific filters in the databases, such as architectural graphics. This manuscript aims to define the research topics and trends in architectural graphics as a point of reference for novel professors and new researchers in graphics or drawing. A database on the Scopus-indexed scientific production of the professors of architectural graphics from public architecture schools in Spain has been developed. Furthermore, cluster and map network analyses have been performed using VOSviewer with different levels of co-occurrence to define what this group of academics investigates and how the issues are related. The results evidenced a structure in four categories: the philosophy and theory of architectural graphics, the theory of geometry in architectural heritage, the application of digital graphics in architecture education and urban design management. Research gaps are mentioned and a base framework for the future of research in architectural graphics is proposed.

Keywords: architecture; design; drawing; geometry; graphic analysis; representation; visual communication

1. Introduction

Graphic representation is the language that allows engineers and architects to communicate ideas that would be very difficult to explain with words. Likewise, it is a challenge to train the skills and abilities required to master this language.

The new didactic approach in higher education combines lectures and interactive sessions, which arises as an opportunity to promote the learning of geometric problems applied to real cases that shed light on the theoretical abstraction that students face. This situation deals with the progressive reduction in course hours regarding the subjects of Graphics (in Spanish, *Expresión Gráfica*) [1], both architectural and engineering graphics. Faced with this readjustment of schedules, students have less opportunities to develop and assimilate essential skills and content for their professional practice as professionals of engineering or architecture.

Professors of engineering graphics have initiated an adaptation to the European Higher Education Area (EHEA) regarding the practical application of a diversity of teaching methodologies [2]. However, the presence of ICT-based methods is very low, even though they stimulate professors and encourage the proactive attitude of students and develop their spatial capacity [3]. Furthermore, Redondo et al. brought to light the need to promote research to improve teaching in architectural graphics, in a

manuscript in which the sources were basically from engineering graphics [4], which provides a vision of convergence.

Both architecture and engineering entail strong professional components which share the need to technically communicate accurate information. Therefore, orthogonal representation or axonometric views are useful for the plans of a house (architecture), an object (manufacturing engineering) or a bridge (civil engineering), among other disciplines. However, architecture requests to represent relevant issues far from the technical approach, such as the haptic perception of space and the big idea or decision behind a design proposal (also known as *parti*). It is, therefore, appropriate to learn from other graphic disciplines to develop a framework for theoretical and empirical research in architectural graphics.

This paper aims to delve into the research topics and trends in architectural graphics. Engineering graphics references will also be used for this purpose. The literature is structured on the topics of international conferences of engineering and architectural graphics organized in Spain, illustrating different methods of representation useful in scientific research. Subsequently, cluster and map network analyses are conducted on SJR (Scimago Journal Rank) publications and bibliometric data of the architectural graphics faculty of all the Spanish public architecture schools.

The professional nature of architecture has led to less of a scientific research culture than other sciences, accompanied by low production of indexed papers [5]. For this reason, the value of this study lies in the difficulty of finding quality research references, since the databases do not include specific metadata on this area of knowledge.

2. Graphic Analysis Research

Architectural graphics has been mainly understood as descriptive geometry and the analysis of architectural forms. However, there are currently useful applications that offer connections among theory and practice.

The research fields in graphic analysis have been structured considering the topics of the international congresses organized in Spain of engineering and architectural graphics. The reason is that these events include current teaching and research. The following conferences were used as a source of topics: XVIII Congreso Internacional de Expresión Gráfica Arquitectónica (XVIII EGA), XIV Congreso Internacional de Expresión Gráfica aplicada a la Edificación (APEGA 2019) and 29 Congreso Internacional INGEGRAF (INGEGRAF). The contents have been combined in six research fields: techniques and theories of graphic analysis, innovation and creation, design and manufacturing, education, heritage and history and analysis of the territory.

2.1. Techniques and Theories of Graphic Analysis

The first field of research corresponds to the set of techniques and theories of graphic analysis (see Table 1). Its topics are correlated with the other six fields of research since it includes the graphic tools of applied research, among which the following stand out.

Table 1. Research field 01: Techniques and theories of graphic analysis.

Conference	Research Topics
EGA	Theories, principles and masters; graphic representation; graphic analysis; geometry and projection; scale models, models and prototypes
APEGA	ICT applications; architectural drawing; graphical analysis of the building; virtual and augmented reality; BIM technology
INGEGRAF	Virtual approaches to interactive design; virtual design based on the prototype; CAD, CAE, IFC and BIM; image processing and analysis; geometric modeling and analysis; reverse engineering; virtual and augmented reality; building information modeling; photogrammetry and remote sensing

- Representation and graphical analysis. This topic includes research such as the study of urban representations in Leonardo da Vinci's manuscripts [6], formal and composition analysis [7], descriptive analysis of buildings [8], the model as an analytic tool in training [9], the historical analysis of the city of Cádiz [10], the elaboration of graphic criteria through the first planimetries of the Granada territory [11], the thought of fundamental graphic elements, such as the line [12], or the solution of complex geometries in the case of fire [13]. The analysis of architecture and urban planning from graphic techniques has been the most important set of methods throughout history. These contributions are of great interest as they provide a scientific approach in terms of explaining the research procedure, design and data collection.
- Photogrammetry consists of the three-dimensional digital representation of an element from the capture and processing of photographs. Some of its applications are the verification of structures [14], the control and management of land use and coverage [15], structural, stratigraphic and natural scenery analysis for purposes related to archeology, chemistry or biochemistry [16,17]. Other aspects have focused on exploring proposals to evaluate the accuracy and precision of photogrammetric mappings, such as through the variation of the number of control points [18] or the use of sub-pixel technology [19], also presenting the development of automatic procedures that take advantage of satellite images to draw building plans [20]. Both this technology and other surveying procedures, such as laser and LIDAR (Laser Imaging Detection and Ranging) scanners, have brought enormous advances in heritage conservation. This is because they are very accurate documentation methods, especially when working with ancient buildings with structural deformations and cracked, worn or damaged finishes (such as texture and color).
- Computer-aided design (CAD) and Computer-aided engineering (CAE) incorporate graphical tools and methods that benefit from digital environments. Some of its applications are to recreate elements and their subsequent analysis, such as the study of press and beam towers for the extraction of oil from olives [21], the recovery of industrial heritage in educational settings [22] or the digital reconstruction of disappeared historical heritage [23]. CAD has favored many design tasks, such as the tracing technique and the drawing of complex geometries, above all in terms of speed and accuracy. Likewise, it has provided the possibility to model and to display interactive three-dimensional architecture.
- Building information modeling (BIM) is an architectural information management tool arranged in a three-dimensional environment that allows to combine the dispersed information of a project [24]. It has had a great impact on architecture and engineering education through the use of software such as Revit or ArchiCAD [25,26]. It is one of the newer technologies and offers many opportunities to manage and analyze architecture.
- Virtual reality (VR) and augmented reality (AR) have been the focus of research with the aim of providing an immersive visualization of 3D models. They are useful tools for the teaching of architecture projects [27] and for the development renewable energies projects [28]. VR and AR provide an environment to visualize architecture in which the user chooses from where to perceive the building. Therefore, they are an attractive tool in education and an effective tool for assessing projects before spending large amounts of money and building them.

2.2. Innovation and Creation

The second field encompasses innovation and creation research (Table 2). The topics it involves are fundamental in the area of architecture; they correspond to the artistic or creative approach that tries to understand the decisions behind the design, or propose new ones.

Table 2. Research field 02: Innovation and creation.

Conferences	Topics
EGA	Built and unbuilt graphic concepts; graphic concepts of heritage; artistic creations; phenomenology, perception and interaction; shape grammar
INGEGRAF	Creativity and innovation methods; collaborative engineering; management of intellectual and industrial property; design and research methods

These include analyses of documentary sources such as pedagogy manuals on descriptive geometry [29], historical images of architectural heritage [30], foundations of the theory of graphic representation [31] on the appearance of geometric constructions, such as the oval and its application in case studies in the construction of vaults in the 16th century [32], such as color theories in the applied case of Le Corbusier’s combination criteria through a navigable 3D model [33] (see the color analysis result in Figure 1b), and the evolution of hand drawing on digital platforms [34] (see digital sketching example in Figure 1a). In this sense, Figure 1a,b provide a vision of the diversity of graphic contributions, from digital sketching related to the representation of haptic perceptions to the technical analysis on the combination of colors by a renowned architect.

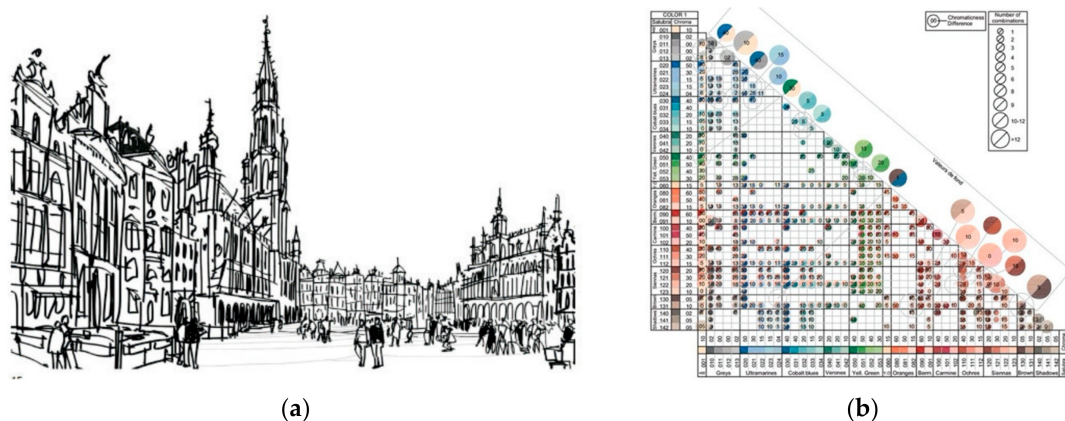


Figure 1. Research field 02 examples: (a) possibilities of freehand drawing on digital tablets. Amado, Antonio, Brujas, 2013. Source: [34]; (b) result of color analysis of all Salubra color pairs. Source: [33].

It also includes contributions to the importance of drawing in architectural thought, as in the case of Rafael Moneo [35], or the analysis of leisure drawings made by architects and their relationship with the first creative sketches of their projects [36], on the qualities of different forms of representation, such as the diagram [37], and the comparison between perspective, photography and infographics [38].

This field also includes geometry theories, such as the design process of complex vaults [39] (see Figure 2c), the geometric and symbolic approaches in medieval Gothic constructions and their comparison with other designs [40] (see Figure 2b), the proportions of the design criteria of ecclesiastical buildings through graphic re-composition [41], the study of its traces [42–44] (see Figure 2a), the categorization of the geometric solutions of vaults in a geographical area [45] and the analysis of dimensions of century walls to find out their construction rules at the end of the 13th century [46]. In this case, the images provide different CAD overlay techniques. First of all, the layout traces are defined on the buildings’ perimeter to locate the complex construction geometries under study. In the second case, a theory of geometric composition is overlaid on a church plan to evaluate whether the architectural design of an ecclesiastical order corresponds to patterns that may be useful for the preservation of the original state of other similar constructions. Finally, a geometry overlay is displayed on the orthophotographs of a typology of vaults to be able to compare them.

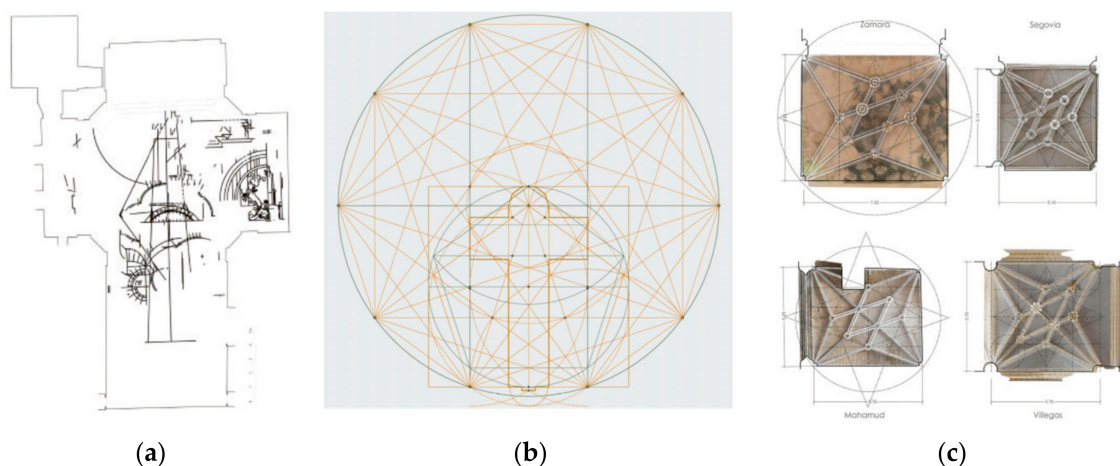


Figure 2. Research field 02 examples: (a) survey of the stonework traces of the church Santa Clara de Santiago. Source: [42]; (b) alternative graphic procedure for the geometric layout of a medieval gothic church of the mendicant order. Source: [40]. (c) Plans of the Spanish vaults by computer-aided design (CAD) overlay on orthophotograph. Source: [39].

2.3. Design and Manufacturing

The third field incorporates the topics of design and manufacturing (see Table 3). Research is related to the process and the possibilities of modeling through CAD software, and its subsequent materialization through digital manufacturing [47], the design of methods for the automatic analysis of the parts that will be physically obtained after modeling to improve performance for subsequent uses [48], the preservation of aerospace heritage through low-cost manufacturing techniques for high-precision models [49] (see Figure 3), 3D scanning for the production of elements, such as prostheses [50], or food to design its packaging [51], and even the generation of ephemeral architecture [52].

Table 3. Research field 03: Design and manufacturing.

Conference	Topics
APEGA	Interior design, technological design and industry; parametric design and digital fabrication
INGEGRAF	Green engineering and eco-design; user-centered design; design based on the product life cycle; robust design, reliability and maintenance; simulation-based modeling and design; ergonomics and human factors; global product development; integrated/advanced manufacturing; manufacturing process and production management; rapid prototyping; additive manufacturing; flexible assemblies; remanufacturing; Industry 4.0

Despite the fact that architectural models have been fundamental elements of ideation, work and communication, there are still not many applied studies on their possibilities. Figure 3 shows the possibility of elaborating full scale high-detail models in an engineering case study. This technology can be useful for prototyping mechanical structures or for experiencing an architectural element through touch.

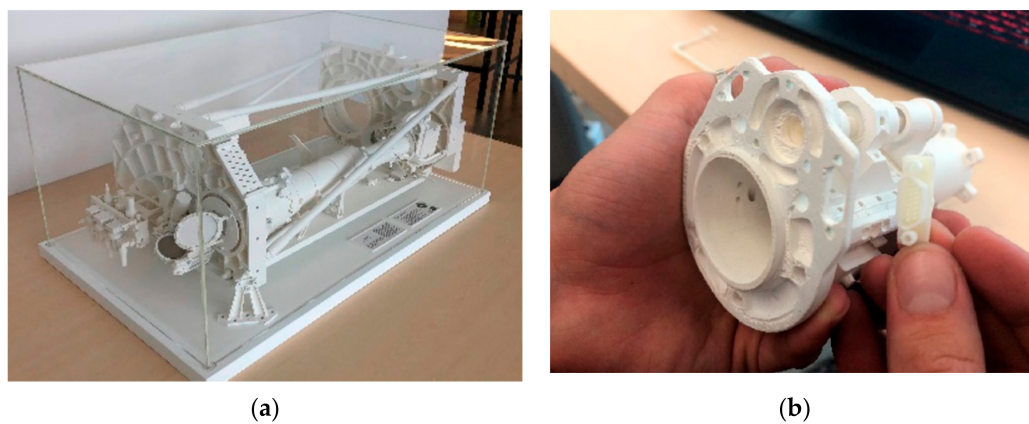


Figure 3. Research field 03 examples: (a) final result of SO/PHI high-detail model Source: [49]; (b) connector and printed piece of Subassembly 8. Source: [49].

2.4. Education

Regarding education (see Table 4), issues related to digital benefits have been explored, such as 3D modeling in universities [53], the possibilities that virtual environments offer to architecture and engineering students [54], the use of augmented reality [3,55,56], smartphones [57] and innovation of teaching methods for learning the cadaster and remote sensing [58].

Table 4. Research field 04: Education.

Conference	Topics
EGA	Theories and didactic models applied to architectural graphic expression; formal and informal learning; new media and contexts; interdisciplinary collaborations and contributions; teaching the graphic representation of architectural heritage
APEGA	Teaching innovation
INGEGRAF	Teaching of graphic expression; theoretical and applied geometry; graphic design; new approaches in teaching–learning processes; project-based learning; interactive 3D modeling

Didactic innovations have also been provided, such as the inclusion of active methodologies in descriptive geometry to promote critical thinking [59] and the introduction of collaborative modeling environments for project management demanded by Industry 4.0 [60]. Spatial skills have been a special focus of interest, methods for their training have been proposed [61,62] and the effect of different digital tools on improving this competence has been compared [63], as well as the improvement of other skills, such as graphic creativity through digital manufacturing techniques [64].

The implementation of augmented reality has been very promoted in the last decade to improve graphic skills, satisfaction, motivation or performance in learning urban planning, constructive elements (see Figure 4b) and musical instruments [65–67]. The first case comes from an interactive explanation of the phases to draw an architectural drawing in which annotations were also added, which goes beyond the problem of drawing on paper in a lecture class. In the second case, the use of a mobile device is shown to apply AR technology to display a 3D model in the student environment, which allows comparing and perceiving its dimension.

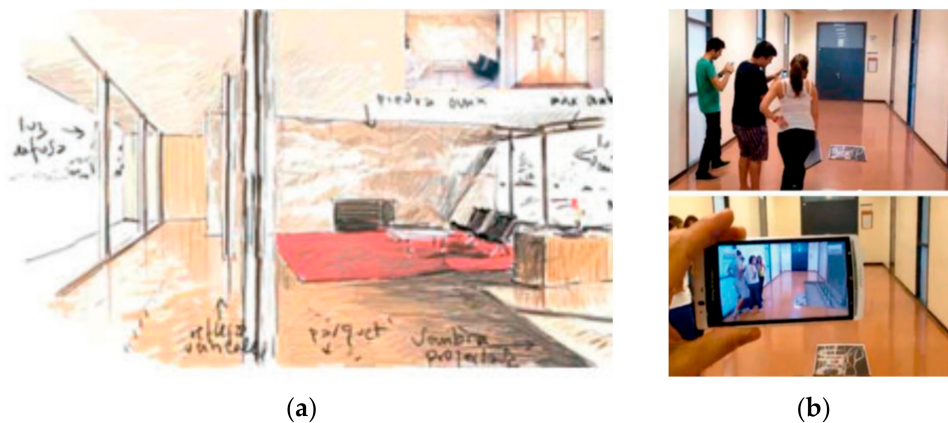


Figure 4. Research field 04 examples: (a) digital sketch example—professors used this method to show the phases of an architectural drawing with annotations. Source: [68]. (b) Students observe a construction process with augmented reality. Source: [66].

This field is consistent with the teaching function of researchers at Spanish universities, which is to improve their teaching based on empirical evidence. Sharing these findings and disseminating research allows for collaborative improvement of architecture training. There are still many untapped possibilities that we can subtract from the rest of the research fields of this framework.

2.5. Heritage and History

A research field of increasing interest is related to heritage and history (see Table 5). It includes urban studies, such as the transformation analysis of the historic core of a city or a town, such as the case of Oviedo [69] (see Figure 5a), or on the original color of these places to restore their chromatic characteristics [70].

Table 5. Research field 05: Heritage and history.

Conference	Topics
EGA	Documentation and graphic restitution; low-tech/high-tech interactions between tradition and innovation; analysis techniques; reconstruct and show what is no longer there; virtual and augmented reality to communicate and interpret the present, the past and the future; architectural heritage survey
APEGA	Drawing in the history of construction
INGEGRAF	Virtual environments; augmented reality in architecture, engineering and construction heritage and territory; conservation of industrial heritage

It also comprises research on industrial and architectural heritage regarding their descriptive and functional digital modeling [71,72], including anastylosis processes [73] (see Figure 5b) as well as the detection of peculiar construction solutions, the definition of a chronology of their construction phases and the collection of important data related to the restorations [74] (see Figure 5c), the digital recovery of ancient engineering techniques, such as the metallurgical case of the Almadén mines [75], or archaeological sites from the Bronze Age [76].

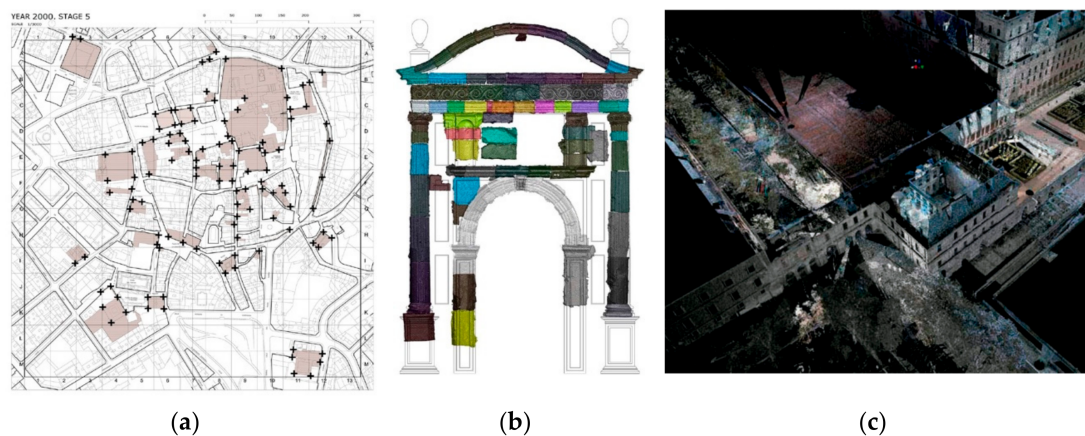


Figure 5. Research field 05 examples: (a) Workspace indicating the historical reference points used. Source: [69]. (b) Superposition of the elevation on the result of the alignment of the main parts of a frame. Source: [73]. (c) Aerial view of the 3D textured model of the area surrounding *la Botica*. Source: [74].

Other studies have proposed procedures to develop the BIM model that relates the historical information and the development of the life of a building [77], to define different levels of knowledge [78] or to obtain high-detail BIM models considering the complexity and deformations of historic buildings [79,80]. In addition, the precision of historical maps of the same city has been compared through carto-metric analysis in order to know the veracity of its geometric precision [81].

Heritage analysis has been the focus of research in architecture. This translates into a visible richness in these examples, showing a wide variety of graphical techniques to answer different research objectives. In the first case (Figure 5a), CAD techniques are used to locate historical reference points. In the second (Figure 5b), the vision on the data management through BIM of an anastylosis procedure is provided in which each color contains a type of information. The third one (Figure 5c) provides an example of surveying with a point cloud photo-texture, combining accuracy and color.

2.6. Analysis of the Territory

Territorial analysis techniques and tools have also become an essential line of research (see Table 6). Some of the examples explore information processing through Geographic Information Systems (GIS) and its various practical applications.

Table 6. Research field 06: Analysis of the territory.

Conference	Topics
EGA	Historical and historiographic cartographies; new cartographies (Space Syntax, GIS, BIG DATA, analytical, perceptual, subjective cartographies, etc.); landscape representation (urban landscape, storytelling, urban sketching, etc.)
APEGA	Topography and cartography; remote sensing and GIS; technical projects; visual communication and smart city
INGEGRAF	Sustainable building; sustainable construction; geoinformation; data capture; urban regeneration

These include cartographic management, space planning, land and resource assessment or planning in areas such as agriculture and environmental studies [82,83], the elaboration of plans on seismic parameters [84] or the development of a dynamic spatial model to visualize and analyze the built heritage on a territorial scale [85] (see Figure 6c).

Another representation possibility consists of the comparison of procedures to map urban areas using mobile and fixed systems [86]. In this context, photogrammetric techniques have been applied to obtain measurements related to the geomorphology of the terrain or the geometry of facilities in urban areas [87–89], as well as for the detection of volumetric or shapes changes due to erosion [90,91].

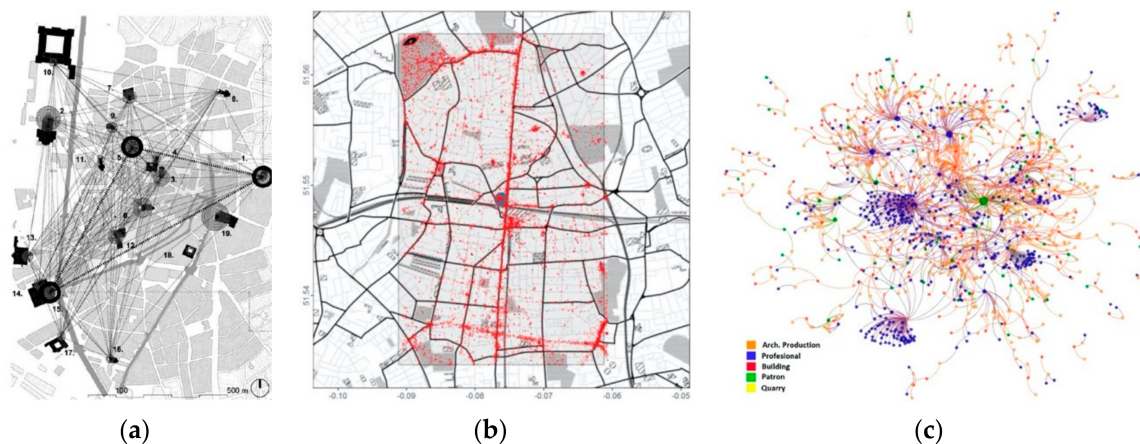


Figure 6. Research field 06 examples: (a) carillon signage analysis. Source: [92]. (b) Location of geo-located images around the case study. Source: [93]. (c) Graphic model in which the node is proportional to the number of activities carried out by professionals. Source: [85].

Information layer overlays have also been applied in order to identify urban realities, such as those related to noise pollution [92] (see Figure 6a), or data mining from digital networks to identify spatial patterns related to an architectural work as well as its area of influence [93] (see Figure 6b). In addition, graphic evaluation tools have been utilized for the evaluation of urban interventions [94], including the manufacture of urban models as a production for transfer to society [95].

Although urban management has been the subject of study since the development of the first cities, new information management methods allow evaluations of a large amount of information. In addition, it is possible to vary the types of criteria and analysis to know the use of human beings on the territory, establish relationships and patterns or develop predictive models of the city. Some of these examples are arranged in Figure 6, in which it is analyzed through citizen participation that is georeferenced in Instagram photographs (Figure 6b) and patterns are generated from built architectural heritage. On the other hand, Figure 6a shows CAD overlay methods that are used to perform analyses that, far from being so technical, allow us to reflect on what mobility patterns were like in the city based on issues such as the sound of church bells.

3. Materials and Methods

This graphical analysis review includes both architectural and engineering references. However, the previous research fields do not necessarily reflect the whole reality of architectural graphics research. This article aims to define the trends and research topics in architectural graphics.

This research follows an empirical documentary design based on textual data of the scientific papers by the architectural graphics professors of all the Spanish public architecture schools. The web page of each architecture department was accessed to prepare a list of the architectural graphics professors in Spain. Then, their Scopus profiles were searched and the list of manuscripts from each professor was collected along with their bibliometric information. Note that only documents dated until 2019 were included. In this process, up to five profiles of the same professor appeared due to variations of their name in the metadata.

Subsequently, network maps and cluster analyses based on written sources were applied through VOSviewer to obtain a co-occurrence map that evidences the frequency and networks of the most

used terms in titles, abstracts and keywords. This system counts the frequency of use of each term and allows establishing a minimum value of occasions in which a term appears to be included in the analysis (a minimum level of relevance) and displays bibliometric maps which are especially useful for displaying a large amount of information in an easy-to-interpret way [96]. Therefore, an exploratory top-down procedure has been performed (from the generic to the particular) to provide a solid structure of the research trends in architectural graphics. Previous researchers have evidenced the usefulness of clustering scientific publications through VOSviewer [97], and in addition to that, its interactive interface is very useful for exploratory studies [98].

3.1. Source of Information

Many bibliometric studies use a WoS (Web of Science) or Scopus database. In Spain, the *Comisión Nacional Evaluadora de la Actividad Investigadora* (CNEAI) assumes a high quality of Scopus journals in the area of architecture. The Scopus database has been considered because it represents the sample of architecture research better than WoS as it provides a broader vision. Otherwise, the sample would be much smaller and representation would not be provided.

3.2. Sample

The sample consisted of 292 architectural graphics professors. The typology of manuscripts under analysis is papers with a number of 384 contributions from 2004 to 2019.

4. Results

4.1. Cluster and Network Map Analyses: Co-Occurrence Fields—Title and Abstract

Written information was obtained from the title and abstract fields of all the publications indexed in Scopus by the architectural graphics faculty following the complete count method, amounting to a total of 10,551 terms. The minimum value of co-occurrence of the terms was experimented with values between 2 and 10 times. The need to test different values lies in the number of publications in the study. In this case, two models are proposed (co-occurrences of 5 and 8) that correspond to two different levels of definition of the constructs. This exploratory strategy aims to validate the structure. The results have proven the robustness of the general structure and, on a deeper level, the interrelation of topics due to the possibility of applying each graphical method to analyze them. In other words, the holistic structure is maintained but relationships between the categories can be understood.

Co-occurrence model 8 (see Figure 7): 369 terms meet this limit, for which the analysis establishes an importance value. This was used to select the 60% of the most relevant terms ($n = 221$) to perform the graphical network map analysis. A model structured in four clusters was obtained with 7898 links and a total link strength of 33,946. The color indicates the cluster in which the word is included. The size of the circle represents the number of publications in which each word appears. The approximation between the different points means a higher correlation, as well as between the clusters.

- The first cluster (red color) contains 72 terms that falls under the philosophy and theory of architectural graphics. Those that are repeated the most are drawing, architect, shape, landscape, art, perspective, color, house, diagram, language, model, photography and sculpture.
- The second cluster (green color) is made up of 67 terms concerning the theory of geometry in architectural heritage. The most repeated terms are vault, survey, map, church, tower, wall, surface, photogrammetry, history, wall, conservation, dome, layout, historical heritage, cathedral, cartography, proportion, arch and GIS.
- The third cluster (blue) includes 44 terms on the application of digital graphics in architecture education. Among those that stand out are technology, student, proposal, user, education, motivation, evaluation, visualization, motivation, augmented reality, mobile device, teaching, satisfaction, 3D model, virtual model and virtual reality.

- The fourth cluster (yellow color) includes 34 terms that comprise urban design management, and the most repeated terms are frame of reference, management, intervention, housing, simulation, interaction, workshop, planning, organization, energy, behavior, urban space and urban planning.

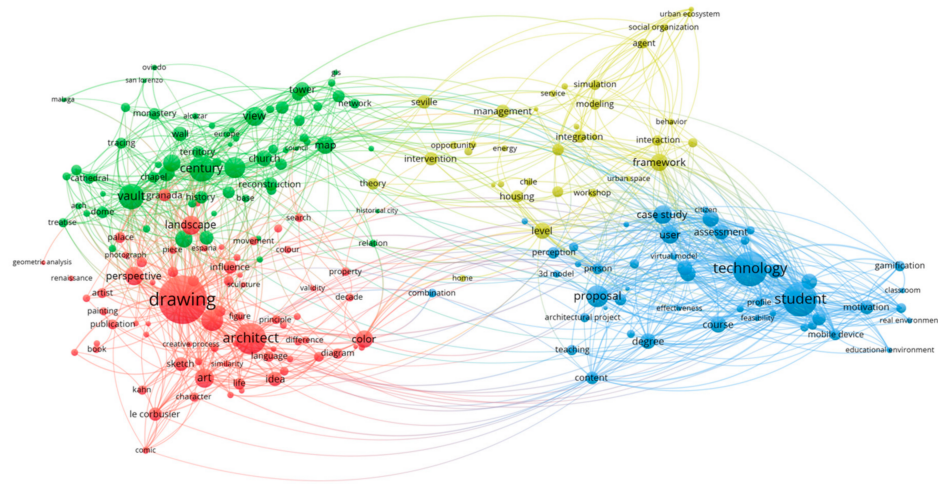


Figure 7. Title and abstract network map of Scopus papers of architectural graphics professors. Minimum level of co-occurrence of eight. Result: four clusters.

In addition, Table 7 provides numerical information on the five concepts with the most weight in each category, including direct links, total link strength and the number of times they appear in the search (occurrence).

Table 7. Results of weight in the structure of title and abstract co-occurrence eight.

Cluster	Label	Weight (Links)	Weight (Total Link Strength)	Weight (Occurrences)
1	drawing	179	2089	234
	architect	170	1238	121
	form	153	859	72
	art	117	803	59
	landscape	124	652	59
2	vault	105	1003	89
	century	159	939	90
	survey	152	862	66
	view	153	764	60
	map	97	579	53
3	technology	154	2126	143
	student	123	2115	140
	case study	127	853	56
	proposal	160	846	71
	user	93	768	54
4	framework	136	759	52
	integration	114	474	30
	communication	89	386	28
	intervention	99	370	34
	management	89	349	34

Co-occurrence model 5 (see Figure 8): 638 terms meet this limit, of which 60% of the most relevant terms is 383. A model structured in seven clusters was obtained with 10,289 links and a total link strength of 36,168.

Testing different levels of co-occurrence provided variations that allow for identifying research fields in architectural graphics. Besides, the visual information on the network map provides valuable information on how the topics complement each other. This information is supported in Table 8 with numerical information on the five concepts with the most weight in each category.

Table 8. Results of weight in the structure of title and abstract co-occurrence five.

Cluster	Label	Weight (Links)	Weight (Total Link Strength)	Weight (Occurrences)
1	architect	232	1397	121
	art	154	999	59
	form	202	916	75
	landscape	150	631	50
	idea	146	595	40
2	student	168	2171	140
	technology	192	1953	128
	case study	171	860	56
	user	111	771	54
	evaluation	131	685	47
3	view	193	792	60
	vault	107	779	83
	perspective	144	551	56
	cathedral	84	313	24
	collection	124	313	25
4	color	69	570	52
	influence	115	370	33
	criterium	77	277	25
	planning	95	244	16
	position	72	229	14
5	tower	52	424	40
	conservation	90	367	31
	monument	89	325	28
	palace	72	265	27
	photogrammetry	81	227	26
6	territory	107	346	31
	cultural heritage	103	338	26
	housing	54	331	31
	decision	76	198	11
	cartography	68	174	19
7	integration	136	539	30
	agent	70	467	22
	interaction	99	423	25
	communication	101	390	28
	simulation	86	370	25

4.2. Cluster and Network Map Analyses: Co-Occurrence Fields—Keywords

The written information corresponds to the keywords of the publications (see Figure 9)—a total of 2346 terms. The minimum value of co-occurrence of the terms between 2 and 5 was experimented with due to the low number of manuscripts. A co-occurrence model five is proposed with 110 terms that meets this limit. A structured model is obtained in four clusters with 10,289 links and a total link strength of 36,168.

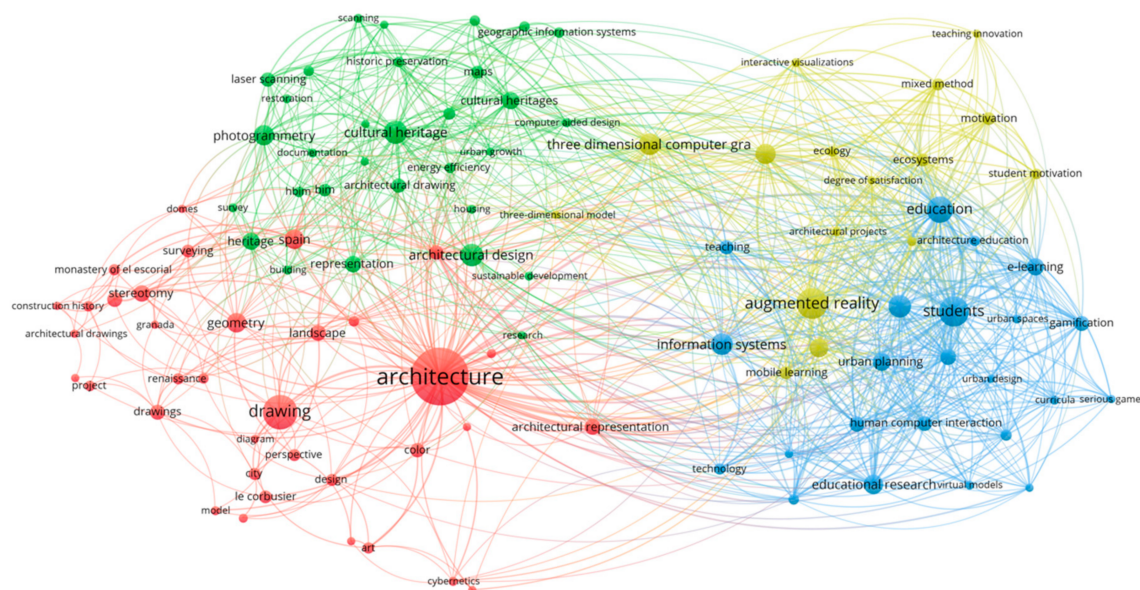


Figure 9. Keywords network map of Scopus papers of architectural graphics professors. Minimum level of co-occurrence of five. Result: four clusters.

- The first cluster (red color) contains 36 terms that are framed in fundamental elements of architectural graphics, such as architecture, survey, geometry, architectural representation, drawing, landscape, stereotomy, design, color, city, perspective, art, sketch, photography, mockup and diagram.
- The second cluster (green color) consists of 31 terms on digital graphic techniques; among the most repeated are cultural heritage, photogrammetry, computer-aided design, architectural design, maps, laser scanner, historical preservation, representation, cartography, GIS, HBIM, BIM, archeology, sustainable development and restoration.
- The third cluster (color blue) includes 23 terms on interactive architecture education tools: education, students, virtual reality, mobile devices, gamification, human-computer interaction, academic performance, architecture education and virtual models.
- The fourth cluster (yellow color) includes 16 terms on innovative visual methods to communicate architecture: three-dimensional computer graphics, augmented reality, visualization, user experience, three-dimensional model, motivation, interactive visualization and satisfaction.

Table 9 incorporate numerical information regarding the weight of those concepts with more importance in terms of weight for each category.

Table 9. Results of weight in the structure of keywords co-occurrence of five.

Cluster	Label	Weight <Links>	Weight <Total Link Strength>	Weight <Occurrences>
1	architecture	92	307	89
	surveys	43	66	11
	geometry	22	35	18
	architectural representation	21	31	13
	drawing	16	31	41
2	cultural heritage	45	103	23
	photogrammetry	39	70	19
	maps	26	51	10
	architectural design	27	43	22
	historic preservation	23	43	7
3	students	46	272	34
	education	51	217	28
	virtual reality	43	137	22
	education computing	39	119	13
	e-learning	37	114	15
4	augmented reality	48	218	35
	three dimensional computer graphics	55	146	21
	visualization	45	140	19
	user experience	38	117	17
	motivation	28	94	10

5. Discussion and Conclusions

Graphic representation requests research references that provide practical applications for drawing professors and researchers. In addition, it is essential to disseminate findings to contribute to the generation of widely proven theories. This is even more important when previous research showed low scientific production in graphic areas [99].

Thus, the scope of literature has included both engineering and architectural graphics in order to combine their knowledge. It has been categorized into six research fields based on international conferences organized in Spain: techniques and theories of graphic analysis, innovation and creation, design and manufacturing, education, heritage and history and analysis of the territory.

The paper has focused on architectural graphics. The cluster analysis on the publications indexed in Scopus has revealed that the research is divided into four areas: the philosophy and theory of architectural graphics, the theory of geometry in architectural heritage, the application of digital graphics in architecture education and urban design management. This result has been verified using two map network models (8 co-occurrences of titles and abstract and 5 co-occurrences of keywords) and has been supported by a third model with a lower limit value in order to deepen our understanding of subcategories, which has evidenced the inter-relation of graphic techniques among topics. In addition, the keyword model has complemented the previous findings as it provides a grouping into four types of graphic methods: fundamental elements of architectural graphics, digital graphics techniques, interactive architecture education tools and innovative visual methods to communicate architecture.

This fact shows a variance of research topics among those proposed by congresses and those published in papers, which proves the existence of gaps in architectural graphics research. This framework of disconnection among sources of knowledge is still a major problem that may be related to the professional load of architecture practice and, consequently, a low scientific production [5].

Regarding topics, the predominance of an architecture research field concerning its artistic nature has been confirmed, in which the most repeated concepts are art, form, idea or drawing. Meanwhile, digital manufacturing is one of the graphic analysis research fields that architects are not exploring and that could be used to manufacture high-detail models [49], to produce ephemeral elements [52] or to develop mechanical prototypes.

Academics and professionals are encouraged to add a global term such as architectural graphics in addition to stating their specific keywords when publishing their research results and not to repeat terms that already appear in the title or abstract.

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References

1. Saorín, J.L.; Navarro, R.; Martín, N.; Contero, M. Las Habilidades Espaciales Y El Programa De Expresión Gráfica En Las Carreras De Ingeniería. *Encuentro Int. Enseñanza Ing. Civ.* **2003**. Available online: <http://www.regeo.uji.es/publicaciones/SNMC05.pdf> (accessed on 5 July 2020).
2. Pena, V.L.; López-Chao, V.A.; L-Chao, A.M. Analysis of teaching methods in graphic design in the Galician university system (GUS) in Spain. *Anthropologist* **2016**, *25*, 214–219. [\[CrossRef\]](#)
3. Martín-Gutiérrez, J.; Saorín, J.L.; Martín-Dorta, N.; Contero, M. Do video games improve spatial abilities of engineering students? *Int. J. Eng. Educ.* **2009**, *25*, 1194–1204.
4. Redondo, E.; Fonseca, D.; Giménez, L.; Santana, G.; Navarro, I. Alfabetización digital para la enseñanza de la arquitectura. Un estudio de caso. *Arquitecturavista* **2012**, *8*, 76–87. [\[CrossRef\]](#)
5. López-Chao, V.; Amado Lorenzo, A. Research training impact on the SJR scientific production of Architectural Graphics. *Rev. Española Doc. Científica* **2020**, in press.
6. García, D.H.; Doménech, S.G. Urban graphic representation in Leonardo da Vinci's manuscripts. *EGA Rev. Expr. Graf. Arquít.* **2017**, *29*, 128–135. [\[CrossRef\]](#)
7. Llopis Verdú, J. El claustro del Colegio de Corpus Christi de Valencia. Análisis formal y compositivo. *Arch. Esp. Arte* **2007**, *80*, 45–65. [\[CrossRef\]](#)
8. Bañón, J.J.P. Dos fragmentos de otaiasa en la universidad laboral de sevilla: Cinco gimnasios y un taller en agonía. *RA Rev. Arquít.* **2008**, *10*, 69–84.
9. Carazo Lefort, E.; Galvan Desvaux, N. Aprendiendo con maquetas. Pequeñas maquetas para el análisis de arquitectura. *EGA. Rev. Expr. Graf. Arquít.* **2014**, *19*, 62–71. [\[CrossRef\]](#)
10. Granado Castro, G.; Barrera Vera, J.A.; Aguilar-Camacho, J. The scale model of Cadiz 1779: Military utility or power metaphor. *Rev. Proy. Prog. Arquít.* **2016**, *15*, 16–29.
11. García-Pulido, L.J. The graphical representation of the territory of granada in the topographic maps of the nineteenth century. *EGA Rev. Expr. Graf. Arquít.* **2016**, *27*, 242–253. [\[CrossRef\]](#)
12. Ampliato Briones, A.L. Apuntes sobre el origen de la línea. *EGA. Rev. Expr. Graf. Arquít.* **2012**, *17*, 60–67. [\[CrossRef\]](#)
13. Nestares Pleguezuelo, P.; Rubio Romero, J.C.; Martínez Aires, M.D.; Parras Anguita, L. Un paso m'sa allá del triángulo y el tetraedro. El modelo qf7 para el conocimiento del fuego. *DYNA Ing. E Ind.* **2015**. [\[CrossRef\]](#)
14. Roca-Pardiñas, J.; Ordóñez, C.; García-Cortés, S.; Bello, A. Validating The Supporting Structure of A Parabolic Solar Collector Using Close Range Photogrammetry. *Photogramm. Rec.* **2013**, *28*, 211–226. [\[CrossRef\]](#)
15. Larranaga, A.; Alvarez-Mozos, J.; Albizua, L.; Peters, J. Backscattering behavior of rain-fed crops along the growing season. *IEEE Geosci. Remote Sens. Lett.* **2012**, *10*, 386–390. [\[CrossRef\]](#)
16. Manzano-Agugliaro, F.; Corchete, V.; Lastra, X.B. Spectral analysis of tide waves in the Strait of Gibraltar. *Sci. Res. Essays* **2011**, *6*, 453–462.
17. Bestué Cardiel, I.; Gutiérrez Carrillo, M.L. Multidisciplinary, diachronic methodology for the conservation of archeological remains. Restoration of the Arab baths of the San Francisco Parador Hotel in the grounds of the Alhambra (Granada, Spain). *J. Cult. Herit.* **2015**, *16*, 623–631. [\[CrossRef\]](#)

18. Agüera-Vega, F.; Carvajal-Ramírez, F.; Martínez-Carricondo, P. Assessment of photogrammetric mapping accuracy based on variation ground control points number using unmanned aerial vehicle. *Meas. J. Int. Meas. Confed.* **2017**, *98*, 221–227. [\[CrossRef\]](#)
19. Aguilar, F.J.; Nemmaoui, A.; Aguilar, M.A.; Chourak, M.; Zarhloule, Y.; García Lorca, A.M. A quantitative assessment of forest cover change in the moulouya river watershed (Morocco) by the integration of a subpixel-based and object-based analysis of Landsat data. *Forests* **2016**, *7*, 23. [\[CrossRef\]](#)
20. Agüera, F.; Liu, J.G. Automatic greenhouse delineation from QuickBird and Ikonos satellite images. *Comput. Electron. Agric.* **2009**, *66*, 191–200. [\[CrossRef\]](#)
21. Rojas-Sola, J.I. Ancient technology and computer aided design: Olive oil production in southern Spain. *Interdiscip. Sci. Rev.* **2005**, *30*, 59–67. [\[CrossRef\]](#)
22. Suárez, J.; Rojas-Sola, J.I.; Rubio, R.; Martín, S.; Morán, S. Teaching applications of the new computer-aided modelling technologies in the recovery and diffusion of the industrial heritage. *Comput. Appl. Eng. Educ.* **2009**, *17*, 455–466. [\[CrossRef\]](#)
23. Franco Taboada, J.A.; Goy Diz, A.E. Renaissance drawings of the 16th century in the city of Lugo: Three fountains from Gonzalo de la Bárcena's workshop. *Buildings* **2018**, *8*, 44. [\[CrossRef\]](#)
24. Angulo Fornos, R. Construcción de la base gráfica para un sistema de información y gestión del patrimonio arquitectónico: Casa de Hylas. *Arqueol. Arquít.* **2013**, *9*, 11–25. [\[CrossRef\]](#)
25. Lei, Z.; Quian, R.; Zhang, L.; Tan, P.; Luo, Z.; Bai, L. Application of BIM in Engineering Drawing Course. *Creat. Educ. Stud.* **2019**, *7*, 80–85. [\[CrossRef\]](#)
26. Turk, Ž. *Should BIM Change the Language of Engineering Education?* Budapest University of Technology and Economics: Budapest, Hungary, 2018. [\[CrossRef\]](#)
27. Fonseca, D.; Valls, F.; Redondo, E.; Villagrasa, S. Informal interactions in 3D education: Citizenship participation and assessment of virtual urban proposals. *Comput. Human Behav.* **2016**, *55*, 504–518. [\[CrossRef\]](#)
28. Lizcano, P.E.; Manchado, C.; Gomez-Jauregui, V.; Otero, C. Virtual reality to assess visual impact in wind energy projects. In *Advances on Mechanics, Design Engineering and Manufacturing*; Springer: Berlin/Heidelberg, Germany, 2017.
29. Martín-Pastor, A.; Granado-Castro, G. A Contribution to the Study of Instruction in Geometry and Architectural Representation in Spain during the 17th Century. *Nexus Netw. J.* **2015**, *17*, 231–251. [\[CrossRef\]](#)
30. Gordo, G.; Antonio, J.F. Lewis's original drawings of the alhambra palaces (1832–33). *EGA Rev. Expr. Graf. Arquít.* **2012**, *20*, 74–85.
31. Martín, F.G. Drawer of ideas and builder of images. Foundations for architectural drawing. *EGA Rev. Expr. Graf. Arquít.* **2016**, *28*, 190–197.
32. López Mozo, A. Ovals for Any Given Proportion in Architecture: A Layout Possibly Known in the Sixteenth Century. *Nexus Netw. J.* **2011**, *13*, 569–597. [\[CrossRef\]](#)
33. Serra, J.; Llopis, J.; Torres, A.; Giménez, M. Color combination criteria in le Corbusier's Purist architecture based on Salubra claviers from 1931. *Color Res. Appl.* **2016**, *41*, 85–100. [\[CrossRef\]](#)
34. Amado Lorenzo, A.; Fraga López, F. El dibujante digital. Dibujo a mano alzada sobre tabletas digitales. *EGA. Rev. Expr. Graf. Arquít.* **2015**, *20*, 108–119. [\[CrossRef\]](#)
35. Franco Taboada, J.A. La importancia del dibujo en la obra de Rafael Moneo. A propósito de una exposición. *EGA. Rev. Expr. Graf. Arquít.* **2014**, *19*, 36–45. [\[CrossRef\]](#)
36. Amado, A. Las caricaturas de los arquitectos. *EGA. Rev. Expr. Graf. Arquít.* **2013**, *18*, 96–107. [\[CrossRef\]](#)
37. Marcos, C.L. Ser y devenir de los diagramas. Huellas y protoformas como subtexto arquitectónico: De Deleuze a Eisenman. *EGA. Rev. Expr. Graf. Arquít.* **2012**. [\[CrossRef\]](#)
38. Franco Taboada, J.A. Sobre perspectiva, fotografía e infografía. Apuntes para una fenomenología de la representación. *EGA. Rev. Expr. Graf. Arquít.* **2011**, *16*, 54–64. [\[CrossRef\]](#)
39. López-Mozo, A.; Senent-Domínguez, R. Late Gothic Asymmetrical Diamond Vaults in Spain. *Nexus Netw. J.* **2017**, *19*, 323–343. [\[CrossRef\]](#)
40. Tarrio Carrodeagüas, S.B. Geometría y proporción en San Francisco de Orense. *EGA Rev. Expr. Graf. Arquít.* **2012**, *16*. [\[CrossRef\]](#)
41. Calvo-López, J.; Salcedo-Galera, M. Geometrical Proportion in the Sixteenth Century: Methods and Constraints. *Nexus Netw. J.* **2017**, *19*, 155–178. [\[CrossRef\]](#)

42. Calvo López, J.; Alonso Rodríguez, M.Á.; Taín Guzmán, M.; Camiruaga Osés, I. Métodos de documentación, análisis y conservación de trazados arquitectónicos a tamaño natural. *Arqueol. Arqut.* **2015**, *12*, 026. [\[CrossRef\]](#)
43. García-Ortega, A. Reglas de dimensionamiento en trazas tardogóticas españolas. Las catedrales de Sevilla y Segovia. *Inf. Constr.* **2017**. [\[CrossRef\]](#)
44. Pinto-Puerto, F.; Jiménez-Martín, A. Geometric Working Drawing of a Gothic Tierceron Vault in Seville Cathedral. *Nexus Netw. J.* **2016**, *18*, 439–466. [\[CrossRef\]](#)
45. Freire-Tellado, M.J.; Tarrío-Carrodegua, S.B. Las bóvedas pétreas nervadas de Galicia: Identificación de soluciones. *Inf. Constr.* **2015**. [\[CrossRef\]](#)
46. Ortega, A.J.G. Diseño y construcción de muros en el primer gótico cordobés. *Inf. Constr.* **2009**, *61*, 37–52. [\[CrossRef\]](#)
47. Del Río-Cidoncha, M.G.; Martínez-Palacios, J.; Ortuño-Ortiz, F. Task automation for modelling solids with Catia V5. *Aircr. Eng. Aerosp. Technol.* **2007**. [\[CrossRef\]](#)
48. Mercado-Colmenero, J.M.; Paramio, M.A.R.; Perez-Garcia, J.M.; Martin-Doñate, C. A new hybrid method for demoldability analysis of discrete geometries. *CAD Comput. Aided Des.* **2016**, *80*, 43–60. [\[CrossRef\]](#)
49. Saorín, J.L.; Lopez-Chao, V.; de la Torre-Cantero, J.; Díaz-Alemán, M.D. Computer aided design to produce high-detail models through low cost digital fabrication for the conservation of aerospace heritage. *Appl. Sci.* **2019**, *9*, 2338. [\[CrossRef\]](#)
50. Íñiguez-Macedo, S.; Somovilla-Gómez, F.; Lostado-Lorza, R.; Corral-Bobadilla, M.; Martínez-Calvo, M.Á.; Sanz-Adán, F. The design of a knee prosthesis by finite element analysis. In *Advances on Mechanics, Design Engineering and Manufacturing*; Springer: Cham, Switzerland, 2017.
51. Rodríguez-Parada, L.; Pardo-Vicente, M.Á.; Mayuet-Ares, P.F. Digitalization fresh food using 3D scanning for custom packaging design. *Dyna* **2018**, *93*, 681–688.
52. Martín-Pastor, A.; Martín-Mariscal, A.; López-Martínez, A. Rethinking ephemeral architecture. Advanced geometry for citizen-managed spaces. In *Sustainable Development and Renovation in Architecture, Urbanism and Engineering*; Springer: Cham, Switzerland, 2017; pp. 301–310. [\[CrossRef\]](#)
53. Ayala Alvarez, F.J.; Blázquez Parra, E.B.; Montes-Tubío, F.D.P. Incorporation of 3D ICT elements into class. *Comput. Appl. Eng. Educ.* **2017**, *25*, 542–549. [\[CrossRef\]](#)
54. Valls, F.; Redondo, E.; Sánchez, A.; Fonseca, D.; Villagrasa, S.; Navarro, I. Simulated environments in architecture education. Improving the student motivation. In *Proceedings of the Advances in Intelligent Systems and Computing*; Springer: Cham, Switzerland, 2017.
55. Contero, M.; Naya, F.; Company, P.; Saorín, J.L.; Conesa, J. Improving visualization skills in engineering education. *IEEE Comput. Graph. Appl.* **2005**, *25*, 24–31. [\[CrossRef\]](#)
56. Navarro, I.; Galindo, A.; Fonseca, D. Augmented reality uses in educational research projects: The “Falcones Project”, a case study applying technology in the Humanities framework at high school level. In *Proceedings of the ACM International Conference Proceeding Series*; ACM Digital Library: Salamanca, Spain, 2013.
57. de Ravé, E.G.; Jiménez-Hornero, F.J.; Ariza-Villaverde, A.B.; Taguas-Ruiz, J. DiedricAR: A mobile augmented reality system designed for the ubiquitous descriptive geometry learning. *Multimed. Tools Appl.* **2016**, *75*, 9641–9663. [\[CrossRef\]](#)
58. Manzano-Agugliaro, F.; Castro-García, M.; Pérez-Romero, A.M.; García-Cruz, A.; Novas, N.; Salmerón-Manzano, E. Alternative methods for teaching cadastre and remote sensing. *Surv. Rev.* **2016**, *48*, 450–459. [\[CrossRef\]](#)
59. Antón García, D.; Pérez Suárez, M. La docencia universitaria novel como mejora metodológica. *Opcion* **2015**, *31*, 104–124.
60. Saorín, J.L.; de la Torre-Cantero, J.; Díaz, D.M.; López-Chao, V. Cloud-based collaborative 3D modeling to train engineers for the industry 4.0. *Appl. Sci.* **2019**, *9*, 4559. [\[CrossRef\]](#)
61. Martín-Dorta, N.; Saorín, J.L.; Contero, M. Development of a fast remedial course to improve the spatial abilities of engineering students. *J. Eng. Educ.* **2008**, *97*, 505–513. [\[CrossRef\]](#)
62. Sierra-Uria, E.; Garmendia-Mujika, M.; Garikano-Oxinaga, X.; Solaberrieta-Mendez, E. Reading technical drawings: A learning-teaching proposal for engineering schools. *Dyna* **2013**, *88*, 591–600.
63. Ramírez-Juidías, E.; Tejero-Manzanares, J.; Amaro-Mellado, J.L.; Ridao-Ceballos, L. Developing experimental learning in a graphical course using thurstone’s law of comparative judgment. *Eng. Lett.* **2017**, *25*, 1–6.

64. Melian, D.; Luis Saorin, J.; De La Torre-Cantero, J.; Lopez-Chao, V. Analysis of the Factorial Structure of Graphic Creativity of Engineering Students through Digital Manufacturing Techniques. *Int. J. Eng. Educ.* **2020**, *36*, 1151–1160.
65. Redondo Dominguez, E.; Sanchez Riera, A.; Moya Sala, J.N.; Regot Marimon, J. La ciudad como aula digital. Enseñando urbanismo y arquitectura mediante mobile learning y la realidad aumentada. Un estudio de viabilidad y de caso. *Archit. City Environ.* **2012**, *7*, 27–54.
66. Sánchez, A.; Redondo, E.; Fonseca, D.; Navarro, I. Hand-held augmented reality: Usability and academic performance assessment in educational environments. Case study of an engineering degree course. *Information* **2013**, *16*, 8621–8634.
67. Del Rio-Guerra, M.S.; Martin-Gutierrez, J.; Lopez-Chao, V.A.; Parra, R.F.; Ramirez Sosa, M.A. AR Graphic representation of musical notes for self-learning on guitar. *Appl. Sci.* **2019**, *9*, 4527. [\[CrossRef\]](#)
68. Domínguez, E.R.; Roma, G.S. Metodologías docentes basadas en interfases táctiles para la docencia del dibujo y los proyectos arquitectónicos. *Arquiteturarevista* **2010**, *6*, 90–105. [\[CrossRef\]](#)
69. Alonso-Rodríguez, M.; Alvaro-Tordesillas, A.; Carazo-Lefort, E. Infographic restitution of the historic centre of the Spanish town of Oviedo. *Comput. Environ. Urban Syst.* **2017**, *64*, 154–168. [\[CrossRef\]](#)
70. Llopis, J.; Torres, A.; Serra, J.; García, Á. The preservation of the chromatic image of historical cities as a cultural value. The old city of Valencia (Spain). *J. Cult. Herit.* **2015**, *16*, 611–622. [\[CrossRef\]](#)
71. Rojas-Sola, J.I.; De la Morena-De la Fuente, E. Agustín de betancourt's double-acting steam engine: Analysis through computer-aided engineering. *Appl. Sci.* **2018**, *8*, 2309. [\[CrossRef\]](#)
72. Fonseca, D.; Navarro, I.; de Renteria, I.; Moreira, F.; Ferrer, Á.; de Reina, O. Assessment of Wearable Virtual Reality Technology for Visiting World Heritage Buildings: An Educational Approach. *J. Educ. Comput. Res.* **2018**, *56*, 940–973. [\[CrossRef\]](#)
73. Angulo, R.; Pinto, F.; Rodríguez, J.; Palomino, A. Digital Anastylis of the Remains of a Portal by Master Builder Hernán Ruiz: Knowledge Strategies, Methods and Modelling Results. *Digit. Appl. Archaeol. Cult. Herit.* **2017**, *7*, 32–41. [\[CrossRef\]](#)
74. Chias, P.; Abad, T. The Botica or Apothecary in the Monastery of San Lorenzo el real de El Escorial (Madrid, Spain): Written sources, historic drawings, and new surveys applied to architectural analysis. *Buildings* **2018**, *8*, 4. [\[CrossRef\]](#)
75. Tejero-Manzanares, J.; Garrido-Sáenz, I.; Pérez-Calle, M.D.; Montes-Tubío, F. Virtual reconstruction in recovery metallurgical heritage of almaden mines. *Dyna* **2013**, *88*, 299–307. [\[CrossRef\]](#)
76. Carvajal-Ramírez, F.; Navarro-Ortega, A.D.; Agüera-Vega, F.; Martínez-Carricondo, P.; Mancini, F. Virtual reconstruction of damaged archaeological sites based on Unmanned Aerial Vehicle Photogrammetry and 3D modelling. Study case of a southeastern Iberia production area in the Bronze Age. *Meas. J. Int. Meas. Confed.* **2019**, *136*, 225–236. [\[CrossRef\]](#)
77. Rodríguez-Moreno, C.; Reinoso-Gordo, J.F.; Rivas-Lpez, E.; Gmez-Blanco, A.; Ariza-Lpez, F.J.; Ariza-Lpez, I. From point cloud to BIM: An integrated workflow for documentation, research and modelling of architectural heritage. *Surv. Rev.* **2018**, *50*, 212–231. [\[CrossRef\]](#)
78. Castellano-Román, M.; Pinto-Puerto, F. Dimensions and Levels of Knowledge in Heritage Building Information Modelling, HBIM: The model of the Charterhouse of Jerez (Cádiz, Spain). *Digit. Appl. Archaeol. Cult. Herit.* **2019**, *14*, e00110. [\[CrossRef\]](#)
79. Antón, D.; Medjdoub, B.; Shrahily, R.; Moyano, J. Accuracy evaluation of the semi-automatic 3D modeling for historical building information models. *Int. J. Archit. Herit.* **2018**, *12*, 190–805. [\[CrossRef\]](#)
80. Nieto, E.; Moyano, J.J.; García, Á. Construction study of the Palace of the Children of Don Gome (Andújar, Jaén), managed through the HBIM project. *Virtual Archaeol. Rev.* **2019**, *10*, 84–97. [\[CrossRef\]](#)
81. Granado-Castro, G.; Aguilar-Camacho, J. Cartographic style in the first urban maps of Cadiz, Spain: A technique in transition. *Cartogr. J.* **2019**, *56*, 18–41. [\[CrossRef\]](#)
82. Serrano, S.; Jiménez-Hornero, F.J.; Gutiérrez de Ravé, E.; Jodral, M.L. GIS design application for “Sierra Morena Honey” designation of origin. *Comput. Electron. Agric.* **2008**, *64*, 307–317. [\[CrossRef\]](#)
83. Aguilar, F.J.; Fernandez-Luque, I.; Aguilar, M.A.; García Lorca, A.M.; Viciano, A.R. The integration of multi-source remote sensing data for the modelling of shoreline change rates in a mediterranean coastal sector. *Int. J. Remote Sens.* **2019**, *40*, 1148–1174. [\[CrossRef\]](#)
84. Amaro-Mellado, J.L.; Morales-Esteban, A.; Martínez-Álvarez, F. Mapping of seismic parameters of the Iberian Peninsula by means of a geographic information system. *Cent. Eur. J. Oper. Res.* **2018**, *26*, 739–758. [\[CrossRef\]](#)

85. Ferreira-Lopes, P.; Pinto-Puerto, F. GIS and graph models for social, temporal and spatial digital analysis in heritage: The case-study of ancient Kingdom of Seville Late Gothic production. *Digit. Appl. Archaeol. Cult. Herit.* **2018**, *9*, e00074. [\[CrossRef\]](#)
86. Barrera-Vera, J.A.; Benavides-López, J.A. Handheld mobile mapping applied to historical urban areas. *Disegnarecon* **2018**, *11*, 20.
87. Giménez, R.; Marzolf, I.; Campo, M.A.; Seeger, M.; Ries, J.B.; Casali, J.; Álvarez-Mozos, J. Accuracy of high-resolution photogrammetric measurements of gullies with contrasting morphology. *Earth Surf. Process. Landforms* **2009**, *34*, 1915–1926. [\[CrossRef\]](#)
88. Serrano, F.; Saumell, J.; Berenguer, F. Metric results analysis of point cloud and direct measure in building heritage. Sanctuary of “La Montaña” in Cáceres. *Inf. Constr.* **2014**, *66*. [\[CrossRef\]](#)
89. Martínez-Rubio, A.; Sanz-Adan, F.; Santamaría-Peña, J.; Martínez, A. Evaluating solar irradiance over facades in high building cities, based on LiDAR technology. *Appl. Energy* **2016**, *183*, 133–147. [\[CrossRef\]](#)
90. Torrecillas, C.; Berrocoso, M.; Pérez-López, R.; Torrecillas, M.D. Determination of volumetric variations and coastal changes due to historical volcanic eruptions using historical maps and remote-sensing at Deception Island (West-Antarctica). *Geomorphology* **2012**, *136*, 6–14. [\[CrossRef\]](#)
91. Aguilar, M.A.; Nemmaoui, A.; Aguilar, F.J.; Qin, R. Quality assessment of digital surface models extracted from WorldView-2 and WorldView-3 stereo pairs over different land covers. *GISci. Remote Sens.* **2019**, *56*, 109–129. [\[CrossRef\]](#)
92. García Sánchez, M.T. El diseño sonoro de la ciudad: Las campanas de Madrid a manos de Llorenç Barber. *ACE Archit. City Environ.* **2019**, *41*, 109. [\[CrossRef\]](#)
93. Valls, F.; Redondo, E.; Fonseca, D.; Torres-Kompen, R.; Villagrasa, S.; Martí, N. Urban data and urban design: A data mining approach to architecture education. *Telemat. Inform.* **2018**, *35*, 1039–1052. [\[CrossRef\]](#)
94. Cervero Sánchez, N.; Agustín Hernández, L. Evaluación gráfica de la rehabilitación urbana del poblado dirigido de Caño Roto. *ACE Archit. City Environ.* **2018**. [\[CrossRef\]](#)
95. Ortega Vidal, J.; Martínez Díaz, Á.; Muñoz de Pablo, M.J. La representación de la ciudad, entre la planta y el volumen: El plano del Prado y la maqueta de la Gran Vía de Madrid. *EGA. Rev. Expr. Graf. Arquít.* **2012**, *17*, 256–266. [\[CrossRef\]](#)
96. van Eck, N.J.; Waltman, L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* **2010**, *84*, 523–538. [\[CrossRef\]](#)
97. van Eck, N.J.; Waltman, L. Citation-based clustering of publications using CitNetExplorer and VOSviewer. *Scientometrics* **2017**, *111*, 1053–1070. [\[CrossRef\]](#)
98. Leydesdorff, L.; Rafols, I. Interactive overlays: A new method for generating global journal maps from Web-of-Science data. *J. Informetr.* **2012**, *6*, 318–332. [\[CrossRef\]](#)
99. Rojas-Sola, J.I.; Navarrete-Cortés, J.; Fernández-López, J.A.; Chaichio-Moreno, J.A. Scientific production in the graphic expression in engineering area at the Spanish universities: An approach to ISI Database. *Rev. Española Doc. Científica* **2008**, *31*, 190–204. [\[CrossRef\]](#)

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